Structure as a Design Tool

Abstract

This article describes Structural Integrated Design as a design method according to which the structural criterion is taken into account during the process of designing and evaluating the architectural shape, and the structural logic guides and enriches the design process. Therefore the knowledge of structure needs to be translated into a design language describing the world of structure and architecture. By looking at the structural input of a Structural Integrated Design process when architect and structural engineer are working together, I plan to determine the characteristics of such a design process in order to develop this design language.

Structural Integrated Design (SID)

When making an architectural design, many criteria (e.g. budget, function, expression, environment, space quality) have to be taken into account. Structural stability is one of these criteria. Since the shape of the building is directly related to the structure which holds it together, the structural concept of the building is basically designed when the shape is designed. So if we want to control the design of the structural concept, we have to be conscious of the structural implications when designing the shape of the building. The search space[1] of the overall architectural shape – and, as a consequence, of the overall structure – is still large at the beginning of the design process. Therefore it is important to take into account the structural criterion at the beginning of the design process if we want to be able to steer the design of the structure.

At this stage of my work, I call this design process where the structural criterion is taken into account early on, Structural Integrated Design (SID). SID makes the consequence of an architectural decision apparent on the level of the structure of the design and infiltrates the architectural design process with structural logic. The objective of SID is not to design an optimized structure as such, nor to make a design with a strong structural expression. SID is not intended to impose the structural criterion as a conditio sine qua non. Structural stability is only one of the many different design criteria between which the architect needs to find a balance.
The main goal of SID is to understand and evaluate the structural criterion while shaping the design. (The opposite is to design a shape without any kind of structural knowledge involved.)

1 This is the range of possible solutions to a given problem.

The second goal of SID is to guide the design process. Structural logic can be a very powerful tool in structuring both the design itself and the design process. As mentioned above, the search space of the design is still large in the early phase. Structural input can guide this search space towards a consistent and manageable design level, and at the same time inspire the design process. To be able to accomplish this, the structural knowledge needs to be translated into a design language for describing the world of architectural shapes and structural concepts (as opposed to a language for calculating structures[2]).

Although SID is a design method that in principle does not impose a structural criterion on the end result of the design, it is likely that in the final design the structural concept will be an expression of the architectural concept.

When and how does SID happen?

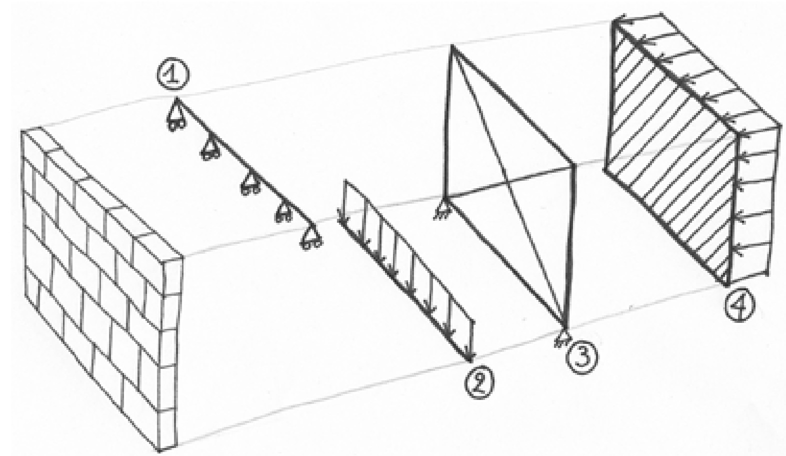
Every building that is built – and still standing – meets the criterion of structural stability. The design of the structure can be divided into two major activities: designing the structural concept and calculating the structural dimensions. The structural concept consists of all the structural elements (e.g. beams, columns, slabs, cables, shells) and their interconnections that determine the whole structure. It is the translation of the physical shape of the building into the structural model. This model and the imposed loads are used to calculate the dimensions of the structural elements. This division of 'concept designing' and 'calculating dimensions' can be applied on all scales of the building: from the overall structure of the building to the smallest detail that needs to be dimensioned.
Designing a structure involves these two activities in a cyclic process where the structural concept is evaluated by the calculated dimensions. This evaluation leads either to accepting the structure, or to refining[3] it, or even to redesigning[4] the basic structural concept.

Calculating the dimensions of the structural concept is basically a procedural activity that can be written in a computer program: input and output have a one-to-one-relationship.
Designing a structural concept, however, is a design activity in every sense of the word. There is no predefined translation from the architectural shape into the structural model. Architectural objects can be translated into different structural objects (and vice versa). For example, a brick wall can be a linear bearing support for vertical loads, a load (weight), a wind bracing, a plate carrying horizontal load (windshield) or even everything together.

2 See further on.

3 This involves only smaller changes of the structural concept.

4 The whole structural concept is altered.

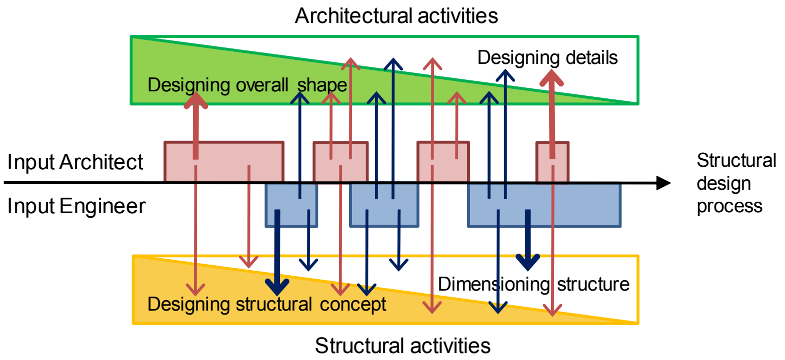


(Fig.1) Translation of a brick wall into structural objects:
1. linear support, 2. load, 3. wind bracing, 4. horizontally loaded plate.

So even with a given architectural shape, different structural concepts can be designed. When the architectural shape is not defined, the search space of the structure is even bigger. But once the structural concept is designed, then the dimensions of the structural elements and their impact on the architectural shape are determined. Therefore the creation of the architectural shape and its structure go hand in hand and need to be treated in that manner.

When a team of architect(s) and structural engineer(s)[5] work together, the structural input during the design process happens both consciously and unconsciously, by architects and by structural engineers: for example, when an architect creates a shape by copying the shape of an existing building without understanding its structure, structural input enters the design unconsciously during the process of shape creation. (The shape will be structurally sound since it is a copy.)

5 Architect is used here to mean an expert in designing architectural shapes, engineer to mean an expert in designing structures.



(Fig.2) Process of designing the structure by architect and engineer

SID means consciously applying structural knowledge when shaping the building and letting structural logic guide the architectural design process. It can be done by the architect and/or by the engineer. SID is about being able to take into account the structural criterion together with the other criteria when evaluating the architectural shape. In our example it would mean that the architect understands the implications on the level of structure when evaluating the copied shape. (If needed, the architect can be assisted by the engineer in understanding the structural implications.)
Understanding the structural implications is not the same as understanding the structure on an engineering level: it is being able to evaluate the structure next to other possible structures, on the basis of architectural design parameters (e.g. expression, flexibility, cost, size, material). For example, one can understand the difference between a Vierendeel girder and a truss beam on the level of architectural expression or sustainability, without having to know the difference in bending moment distribution.

When the engineer as expert in the field of structure and the architect as expert in the field of architecture work together in a creative environment to make the best out of their knowledge of designing and evaluating architectural shapes, they need a common language. My research is about determining this language.

How to make SID happen?

One possible step in promoting SID is to understand the characteristics of its structural input, i.e. when is it needed during the design process and which form does it take? How should the structural knowledge be translated to be designerly usable? What language can be identified as describing the common ground of architectural shaping and structural designing?
If we master this language, we can teach it to architects and engineers for better communication and creative collaboration. Such a language will also open up the opposite field of expertise: making the architect a better structural designer and the engineer a more creative shape designer, so that within their own field of expertise their design ability will improve. Eventually this will lead to more structural integrated design processes in the building practice.

An evident way of looking at the structural input in the design process is by examining the collaboration between the architect and the engineer: this is a clear moment when structural input is given. But not all structural input is part of a conscious process of evaluating the structural criterion. Therefore exemplary design processes need to be examined, in which the structural input is able to guide the architectural shape and influence the architectural concept. This happens when the design team understands the influence of an architectural decision on the structure of the design.
The main research goal is to determine the characteristics of SID within such a design team of architects and structural engineers and, where possible, to improve it.

The material used for this research will be taken firstly from the author's own collaboration as a structural engineer with architects and architectural students, and secondly from collaborations between other engineers and architects. The second source of material will be gathered on an international scale by studying literature describing design practices, and on a local scale by studying Belgian practices through interviews and observations. These collaborations will be chosen with the purpose of their being exemplary for SID.

There are three major phases in the research method. First, a frame of reference will be set up by compiling a corpus of literature studies, case studies and interviews of architects and engineers. Secondly, a model for SID will be established by looking for common 'threads' running through the material thus collected, and by reflecting upon the findings of the first part. And finally, the developed model will be evaluated and refined by implementing it in different case studies.

Long live SID!

In a future where teamwork between different experts within a creative environment is becoming increasingly important, their communication is vital. If we are able to understand and optimize the communication between experts in the field of architecture and experts in the field of structure, we will have created a design language (and not a dimensioning language) that is capable of describing the structural knowledge. This translation of knowledge will be understood by architect and engineer: it will make the architect a better structural designer and the engineer a better shape designer.

For SID it does not matter whether the structural input comes from the architect or the engineer, as long as it enriches the design process and keeps the structural consequences of the architectural decision clear.

Creating a shape involves designing an architectural concept and a structural concept. The two concepts are intertwined and capable of reinforcing and inspiring each other throughout the design process so that in the end they become inseparable. By examining the collaboration between architects and structural engineers, I hope to find a common design language for the two disciplines. This language will not only enhance the communication between architect and engineer, but will also enrich the two disciplines. When a design team uses this language, Structural Integrated Design will follow as a consequence.

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